APPLICATION

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TITLE: **METHOD AND DEVICE FOR TRANSMITTING DATA UNITS OF A DATA STREAM**

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METHOD AND DEVICE FOR TRANSMITTING DATA UNITS OF A DATA STREAM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a method and a device for transmitting data units of a data stream, especially a multimedia data stream from at least one transmitting facility to at least one receiving facility.

2. Discussion of the Related Art

Today's world of entertainment and dissemination of information cannot be imagined without the transmission of real-time media which includes, in particular, the transmission associated with radio broadcasting and television. When he uses these media, however, the consumer still has to accept restrictions at present: the transmissions begin at fixed times and can also be only viewed or "called up" at these fixed times unless video recorders are used.

Some years ago, field trials have been conducted, therefore, involving, among other parties, the Deutsche Telekom AG, where the use of modern communication technology was provided for implementing "video-on-demand". This is a media service in which each customer individually selects the time when he wishes to

view a particular programme (feature film, concert transmission etc.) with the aid of his television set. "Video-on-demand" places very high demands on the technical infrastructure used for it. For example, this relates to the video servers with the aid of which the retrievable media contents are made available and the communication bandwidth necessary when the retrievable media contents are transmitted to a receiving set of the customer. "Video-on-demand" has not, therefore, been previously used in the mass market.

Today, a ("time-independent") individual selectability of media contents mainly only exists in the domain of the Internet (apart from video cassette rental). Media servers deliver individual media contents to the users or customers controlled via Internet pages or other graphical user interfaces.

The methods for the transmission of media contents or multimedia data streams hitherto used in the media domain (for example in television or radio) firstly comprise the abovementioned usual method in which a programme is transmitted "live" to all possible receivers at a fixed transmitting time.

This is different from a transmission on demand, for example "video-on-demand". In this method, it is necessary that the multimedia data stream is transmitted separately for each receiver, for example via ATM, in which arrangement the transmission can be begun on demand, i.e. at a time which can be determined individually. However, the transmission on demand has

the disadvantage that a separate transmission must be performed potentially for each receiver. This increases the necessary total transmission bandwidth of the transmitter in proportion to the number of receivers to be served simultaneously so that this method cannot be used for a large number of receivers, or only with a great expenditure.

In a transmission which is almost on demand and which is also called "near video-on-demand", a number of receivers are combined to form one group. For these receivers, a single joint transmission of the multimedia data stream then takes place. In this method, groups of receivers which would like to retrieve the multimedia data stream within a predetermined period are combined and the transmission of the multimedia data stream begins jointly for all receivers after the predetermined period has elapsed. However, transmission to groups of receivers has the disadvantage that at least some receivers must potentially wait a very long time for the beginning of transmission (if there are few transmissions to a large number of receivers) or the total transmission bandwidth of the transmitter is very large if many transmissions of small groups of receivers are provided.

A periodic transmission method is also known. In the case of a large number of receivers, the transmission requests would have to be processed individually. To avoid this, it may be appropriate to transmit the multimedia data stream or the media content periodically right from the start. A receiver must then

wait for the beginning of the next transmission of the multimedia data stream. To enable the receivers to begin retrieval at predetermined times, the complete multimedia data stream must be transmitted in each case on a number of channels beginning at the possible retrieval times. Periodic transmission has, therefore, the disadvantage that the total transmission bandwidth of the transmitter must be very large, especially if it is intended to provide an adequate number of retrieval start times. Otherwise, the receivers have to wait for a very long time for the beginning of transmission.

Another known method provides that the multimedia data stream is received and stored by the receiver of the consumer at a time at which no reproduction is intended. The automatically stored multimedia data stream can be reproduced later at any time. Storage can in this case be performed selectively for individual multimedia data streams or be permanent. The method of reproducing a stored transmission has the disadvantage, however, that the receiver must select the reception in advance and must have adequate storage capacity.

SUMMARY OF THE INVENTION

An object of the present invention is to create an improved method of the type initially mentioned, in which the disadvantages described are at least partially overcome.

The object is achieved by a method according to Claim 1 and a device according to Claim 14.

The essential advantage achieved by means of the invention, compared with the prior art, consists in that a method is created by means of which a data stream, especially a multimedia data stream, of arbitrary length is transmitted in such a manner that an arbitrary number of consumers are enabled to receive and to consume the data stream independently of one another at different times with the aid of their respective receivers.

Furthermore, an essential aspect of the method according to the invention consists in that the total quantity of the data to be transmitted between the transmitting facility and the receiving facilities does not rise proportionally with the number of receiving facilities. This saves transmission capacities so that the costs are lowered and "video-on-demand" also becomes usable for the mass market.

A data stream transmitted in accordance with the method can be designed as a part of a "higher-level" total data stream.

Fields of application for the method include all applications in which any types of audio/video or other data streams (television, radio, media-on-demand and business TV but also streaming data such as stock market teleprinter etc.) are distributed via satellites, cable networks or the like to groups of consumers with their respective receiving facilities, and the

consumers are intended to have the possibility of being able to choose between data streams.

Furthermore, there are the following advantages in conjunction with the novel method for transmitting data units:

- Entry into a transmission of a multimedia data stream is possible at an (almost arbitrary) time, the granularity of the entry points being dependent on a number of parameters which can be set per media data stream, per group of customers etc.
- The viewing or, respectively, consumption of the multimedia data stream output at the consumer can be interrupted for an arbitrary period of time.
- "Fast forward" and "skipping of parts" after an interruption are possible.
- It is possible to provide different variants of the same programme (for instance a feature film in two modes: with a happy and a tragic end) for the consumers.
- Transmission with different amounts of advertising, with customer-related advertising etc. is possible.

A suitable further development of the invention provides that an input of a user of the at least one receiving facility E_j for establishing the time t_1 and/or the time t_k $(2 \leq k \leq n)$ is electronically detected, the input being transmitted to the at least one transmitting facility via a return data channel formed between the at least one transmitting facility and the at least one receiving facility E_m. As a result, the beginning of the

transmission of the data volumes can be individually established by the users of the receiving facility.

An advantageous embodiment of the invention provides that an essentially equal time interval is in each case formed between the times t_{k-1} and t_k $(2 \leq k \leq n)$, which interval is predetermined at the transmitting end, as a result of which the reproduction of the transmitted data units can be continuously begun by the users of the receiving facilities if the time intervals are sufficiently short.

Further developments of the invention are disclosed in the other claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the text which follows, the invention will be explained in greater detail with reference to exemplary embodiments and referring to a drawing, in which:

Fig. 1 shows a diagrammatic representation of the variation with time of a transmission of a data stream for a receiving facility;

Fig. 2 shows a diagrammatic representation of the variation with time of a transmission of the data stream for two receiving facilities;

Fig. 3 shows a diagrammatic representation of the variation with time of a transmission of the data stream for one or two receiving facilities which in each case have limited storage capacity;

Fig. 4 shows a diagrammatic representation of a first transmission schedule for a transmitting facility for transmitting the data stream;

Fig. 5 shows a diagrammatic representation of a second transmission schedule for the transmitting facility for transmitting the data stream;

Fig. 6 shows a diagrammatic representation of a third transmission schedule for the transmitting facility for transmitting the data stream;

Fig. 7 shows a diagrammatic representation of the variation with time of a transmission of the data stream for one or two transmitting facilities, the transmission being interrupted for a period tU;

Fig. 8 shows a diagrammatic representation of a number of data units of a multimedia data stream;

Fig. 9 shows a diagrammatic representation of a further transmission schedule, some of the data units being transmitted in advance.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A multimedia data stream, for example a feature film, is to be transmitted to an arbitrary number of receiving facilities or, respectively, receivers E_o …. E_j ($j \geq 1$). After it has been received, the feature film is reproduced with the aid of replay means, for example with the aid of a television set or a computer-based monitor and an associated loudspeaker device, which is in each case included in the receiving facilities E_o … E_j or is connected to those in such a manner that the received feature film can be forwarded to the respective television set. In this arrangement, the multimedia data stream (feature film) is (potentially) replayed continuously, i.e. without interruption.

It is assumed by way of example that the data stream containing the feature film to be transmitted can be divided into x data units D_x ($x = 1,2,$ …), each of the x data units D_x comprising at least one data bit and preferably essentially the same amount of data. In principle, the data units D_x are transmitted by the transmitting facility at a transmitting time $t^S{}_x$, received by one of the receivers at a receiving time $t^E{}_x$ and reproduced with the aid of associated replay means at a replay time $t^W{}_x$. To simplify the following representation of the method, the following assumption is made for a data unit D_n ($1 \leq n \leq x$): $t_n = t^S{}_n = t^E{}_n = t^W{}_n$. In fact, however, the receiving time $t^E{}_n$ of

the data unit D_n is later than the transmitting time t^S_n, the time interval between t^S_n and t^E_n depending on the parameters of the transmission between the transmitting facility and the respective receiving facility. Depending on the transmission medium selected, the transmission delay can be constant or can vary, the latter being the case, for example, in IP networks. If the transmission delay varies, a fixed upper limit of the transmission delay can be assumed to simplify matters, or this upper limit can be repeatedly determined dynamically. The replay time t^W_n of the data unit D_n is also displaced by a finite time after the receiving time t^E_n since the data unit D_n, after having been received, must be forwarded to the replay means and converted (several times) for the purpose of reproduction.

In the description following, it is assumed, as a rule, that the transmission begins at time t_n for a receiving device. However, it is also possible that the transmission beginning at time t_n takes place in parallel for a number of receiving facilities, i.e. a number of receiving facilities are "switched in" at time t_n. In this case, the transmitting facility sends out data units which are received by an arbitrary number of receiving facilities. In this arrangement, it can be provided that the data units are transmitted by a number of transmitting facilities. For example, it is provided that, in this case, the individual transmitting facility in each case only sends, once or several times, a particular subset of the data units of the data stream.

According to Figure 1, a total time Δt is needed for replaying the feature film, i.e. all x data units D_x by means of the television set. During this process, the data unit D_n is transmitted at a time t_n after the beginning of the transmission (transmitting, receiving, replaying). This means that the data unit D_n must be transmitted/received and available for replaying at time t_n after the beginning of the replay (or the reception).

The transmission to a receiving facility E_k can begin at a time t^0_k ($k = 0, 1, \ldots$). According to the above assumption ($t_n = t^S_n = t^E_n = t^W_n$), the transmission, the reception and the replaying begin at time t^0_k. From this time on, the receiver E_k (potentially) receives all data units D_x belonging to the feature film. This is illustrated in Figure 1 by means of an entry line 1.

To be able to reproduce the data units D_n in the manner corresponding to the course of the feature film, it is necessary that the data unit D_n must be transmitted at the latest at time $(t^0_k+t_n)$ after the beginning of the transmission of the feature film. If the replaying of the feature film is uninterrupted, the latest transmission times t_n of the data units for the receiver E_k will produce a replay line 2 which begins at $(t^0_k, 0)$ and ends at $(t^0_k + \Delta t, \Delta t)$ (compare Figure 1).

The replay line 2 and the entry line 1 together (with a line $t = \Delta t$) form a triangle, a so-called receiving funnel 3 of the receiver E_k. All data units D_x of the feature film must be transmitted to the receiver E_k within this receiving funnel 3 for

the receiver E_k or its associated replay means to be able to display the feature film completely and continuously.

If the feature film, i.e. the data units D_x are transmitted by the transmitting facility for two receivers E_1 and E_2 (compare Figure 2), the receiver E_2 beginning reception at an entry time $t^0{}_2$ before the transmission of the feature film, begun at entry time $t^0{}_1$, for the receiver E_1 which is already active has concluded, the receiving funnels 4, 5 of the two receivers E_1 and E_2 overlap. If the data unit D_n of the feature film is transmitted at a time within an overlap area 6, this data unit D_n only needs to be transmitted once if both receivers E_1 and E_2 are capable of temporarily storing the data unit D_n in respective storage means up to their respective transmission time ($t^0{}_1 + t_n$ and, respectively $t^0{}_2+t_n$) - the transmitting, receiving and replay time according to the above assumption. This saves the bandwidth otherwise needed for the individual transmission to the two receivers E_1 and E_2. In principle, the data unit D_n is only temporarily stored if the data unit D_n is transmitted before the time at which the data unit D_n is to be replayed in the course of the feature film.

The exemplary procedure described shows that a first data set M_1 which is transmitted to the receiver E_1 or an arbitrary number of other receivers which also opt in at time $t^0{}_1$, for the purpose of transmitting the feature film, comprises all data units D_x of the data stream or feature film, respectively. A

second data set M_2 which is transmitted for the receiver E_2 or an arbitrary number of other receivers which also opt in at time t^0_2, beginning at time t^0_2, however, only comprises some of the data units D_x since the receiver E_2 receives, from time t^0_2 onward, in addition to the data set M_2 intended for this receiver E_2 also the data units of the data set M_1 which are transmitted after time t^0_2.

On the basis of the representation of the method for two receivers E_1 and E_2, the method described can be expanded to a multiplicity of receivers $E_0 \dots E_j$ $(j \geq 1)$. In this connection, two basic variants are possible which can also be combined with one another:

1. Utilization of a return channel

Each of the receivers $E_0 \dots E_j$ $(j \geq 1)$ informs the transmitting facility via an (interactive) return channel about which programme (media content) it wishes to receive at what time. In the example described above, this means that the receivers inform about the time from which the feature film is to be transmitted for the respective receiver. In this manner, each receiver E_k establishes an associated time t^0_k for the beginning of the transmission. From the incoming request of the receivers $E_0 \dots E_j$, the transmitting facility calculates a transmission schedule which describes the order in which data units D_x are to be transmitted in order to be transmitted in each case in the

largest possible number of receiving funnels of the receivers.

2. Transmission without return channel

If no return channel is available between the transmitting facility and the receivers $E_0 \ldots E_j$ or if the number of receivers becomes too large for individual transmission to be possible, the transmitting facility can establish, instead of the times $t^0{}_o \ldots t^0{}_j$ requested by the receivers for the respective beginning of transmission, a predetermined pattern of times for the beginning, for example times at intervals of ten seconds, one minute etc. A receiver then waits until the next predetermined entry time, which is found in the transmitted data stream, and begins replaying only then so that in this case the timing pattern times predetermined by the transmitting facility form or establish the time $t^0{}_0 \ldots t^0{}_j$ ($j \geq 1$).

In both cases, the transmitting facility can determine the time to which the data stream (feature film) can be called up at a maximum, i.e. at which the last transmission request by the receivers may be received which will still be met.

Independently of the availability of one or more return channels, the number of receivers, the regularity of the entry times $t^0{}_0 \ldots t^0{}_j$, the length of the data stream (feature film), the transmitting facility must meet the following requirements when generating and/or dynamically adapting the transmission schedule

for the data units D_x. In principle, the following applies in conjunction with the receiver E_k with the entry time $t^0{}_k$, which is one of the several receivers $E_0 \ldots E_j$ having different entry times $t^0{}_0 \ldots t^0{}_j$:

(a) All data units which are transmitted due to another receiver ($E_0 \ldots E_{k-1}$, $E_{k+1} \ldots E_j$) within the receiving funnel of E_k, do not need to be transmitted again for E_k. In this context, a transmission within the receiving funnel of E_k means that a data unit D_n is transmitted within an interval $[t^0{}_k; t^0{}_k + t_n]$.

(b) A data unit D_m which is not transmitted according to (a) must be transmitted at the latest at time $(t^0{}_k + t_m)$ for E_k so that it can be replayed in accordance with the time sequence of the feature film.

For two receivers E_1 and E_2 (compare Figure 2), the transmission bandwidth is optimally utilized if as many of the data units as possible are transmitted within the two transmission funnels 4, 5, that is to say, in this case, as "close to or along" the replay line of E_1 as possible since all these data units only need to be transmitted once.

At the receiver end, a receiver E_k proceeds as follows from the beginning of reception of the data stream, i.e. of the data units: Data unit D_n, which is to be transmitted during the transmission of the data stream at time t_n, is transmitted (sent, received) at an arbitrary time t_x and

i) transferred to the associated replay facility if $t_x = t_n$;

ii) stored in storage means of the receiver E_k if $t_x < t_n$, i.e. the data unit D_n is needed for replay at a later time and the data unit D_n is not yet present in the storage means;

iii) discarded if $t_x > t_n$, i.e. the data unit D_n is no longer significant for replay at time t_x or is already present in the storage means.

In addition, data unit D_n is taken out of the storage means at time t_s and transferred to the replay facility if $t_s = t_n$ and the data unit D_n has been stored according to ii) or transmitted in advance or distributed (compare description for Figures 8 and 9). In receivers $E_0 \dots E_j$, storage space is thus needed (potentially in the form of a hard disc) on which the data units received and not needed as yet are temporarily stored until the time for replay has come.

As a rule, receivers $E_0 \dots E_j$ only have a finite storage capacity. If the volume of the data units D_x to be temporarily stored at a time is greater than the available storage capacity - for instance if only a maximum of ten minutes of the feature film can be stored at a time - the requirements for the transmitting facility and the receivers $E_0 \dots E_j$ are changed. The receiving funnel 3 is restricted by a storage boundary line 7 (compare Figure 3). Data units, the replay time of which is too far in the future in the case of an early transmission, are not yet stored

on reception. Instead, the system waits for a retransmission at a later time.

For a receiver E_k with the entry time t^0_k, which is one of $E_0 \dots E_j$ receivers with different entry times $t^0_0 \dots t^0_n$, a memory limitation to a period t_{Mem} has the following result:

(a) All data units which are transmitted within the modified receiving funnel of E_k due to another receiver ($E_0 \dots E_{k-1}$, $E_{k-1} \dots E_n$) do not need to be transmitted again for E_k. A transmission within the receiving funnel of E_k means that a data unit D_n is transmitted in the interval at the earliest at time t^o_k and in the interval $[t^0_k + t_n - t_{Mem}; t^0_k + t_n]$.

(b) A data unit D_m which has not been transmitted in accordance with (a), must be sent out at the latest at time $(t^0_k + t_m)$ but not before t^0_k and not before $(t^0_k + t_n - t_{Mem})$.

At the receiver end, the method changes when the parameter t_{Mem} is taken into consideration. At the beginning of reception of a data stream, the receiving facility of a receiver E_k proceeds as follows: the data unit D_n which is to be transmitted at time t_n during the transmission of the data stream, is transmitted (sent, received) at an arbitrary time t_x, and

i) transferred to the associated replay facility if $t_x = t_n$;

ii) stored in storage means of the receiver E_k if $t_x < t_n$ and $t_x > t_n - t_{Mem}$, i.e. the data unit D_n is needed for replay at a later time which, however, is still within the "range"

(storage capacity) of the storage means, and the data unit D_n is not yet present in the storage means;

iii) discarded if $t_x > t_n$, i.e. the data unit D_n is no longer of significance for replay at time t_x or is already present in the storage means or $(t_x \leq t_n - t_{Mem})$.

In addition, the data unit D_n is taken out of the storage means at time t_s and transferred to the replay facility if $t_s = t_n$ and the data unit D_n has been stored according to ii) or transmitted in advance or distributed (compare description for Figures 8 and 9).

According to Figure 3, the overlap area 6 of the receiving funnels 3 of the receivers E_1 and E_2 is reduced in the case where the storage capacity of receivers E_1 and E_2 is limited, as characterized by means of t_{Mem}, to a reduced overlap area 8.

The transmitting and receiving rules specified here for this modification of the method only represent one possible example. Whether data units situated at a time which is also further in the future than t_{Mem} can be temporarily stored depends on the actual transmission schedule. Overall, transmitter and receiver only have to jointly take care that the data unit D_n is present at the receiver at time t_n.

Whereas an implementation algorithm can be derived directly in each case from the methods described above for the receiving end, a number of rules can be specified for the transmitting end which must be fulfilled when a transmission schedule is generated

for transmitting the data units D_x by means of the transmitting facility.

In the text which follows, a possible transmission method which satisfies the above rules and is simple to implement is described by way of example. After that, three procedures for generating a transmission schedule for the data units are described by way of example. Other forms of implementation are also conceivable both for the transmission method and for generating the transmission schedule.

In the exemplary generation of a transmission schedule for the data stream to be transmitted from the transmitting facility to the receivers, the following rules are taken into consideration:

1) The data stream is transformed into a transmittable data stream by dividing the data stream into preferably equally large, mutually delimitable data units D_x ($x = 1, 2, \ldots$). The data units D_x can be as small as required and can comprise even individual bytes or bits in the extreme case. These mutually delimitable data units D_x are also called "slots".

2) The data units D_x are in each case transmitted as late as possible, i.e. as close as possible to the replay line of the receivers $E_0 \ldots E_j$ so that the data units D_x are in the largest possible number of receiving funnels of the receivers $E_0 \ldots E_j$ in order to minimize the bandwidths used for the transmission.

3) To achieve a utilization of the transmission medium which is as uniform as possible or, respectively, to avoid temporary overloading, data units can be sent already at an earlier time. This makes it possible to compensate for peak loads but the data unit sent too early may have to be sent again since, with the early transmission, it could be in the receiving funnel of fewer receivers than would be the case if the data unit had not been sent too early. Avoiding peak loads is then in conflict with the minimization of the data volume transmitted overall.

In the text which follows, three examples for the distribution of the data unit D_x (transmission schedule) for transmission are specified. It is assumed that all data units D_x comprise information of the same duration, i.e. a feature film segment of the same duration in the case of the feature film. At the same time, the duration of one data unit defines the granularity of the entry times t^0_j ($j \geq 0$) for receivers E_j ($j \geq 0$). If a data unit lasts ten seconds, a new (virtual) receiver is assumed every 10 seconds in this method without return channel, i.e. new viewers can be added every ten seconds in order to view the feature film from the start. In the representation following, the data units D_x ($x = 1, 2\ldots$) are numbered consecutively.

The embodiments described in the text which follows are only examples. In addition, the method permits:

- that the size/duration of the data units is not equal,
- that the duration of the data unit and the granularity of the entry times t^0_j $(j \geq 0)$ are different and/or
- that the entry times t^0_j $(j \geq 0)$ can be arbitrarily distributed with and without return channel.

Figure 4 shows an example of a harmonic transmission schedule, the data stream to be transmitted being subdivided into seven data units $D_1 \ldots D_7$. The time axis is subdivided into intervals of equal length, the intervals corresponding to the duration of the seven data units D_x. For the transmission, the data units $D_1 \ldots D_7$ are distributed over the time intervals for the transmission in accordance with a simple rule: data unit D_n having consecutive number n is transmitted in every nth interval, i.e. the first data unit D_1 in every interval, the second data unit D_2 in intervals 2,4,6 …, the third data unit D_3 in intervals 3,6,9, … etc. The possible entry times $t^0_j(j \geq 0)$ for receivers $E_j(j \geq 0)$ are formed by the respective starting times of the intervals (compare Figure 4).

For a first receiver E_0, a data set M_0 which comprises all seven data units $D_1 \ldots D_7$ is transmitted according to Figure 4. The data units transmitted for the first receiver are designated by reference symbols 1a to 1g. If a second receiver E_1, for which the data stream is to be transmitted beginning at t^0_1 is additionally connected at time t^0_1, a data set M_1 transmitted for

the second receiver E_1 only comprises the data unit D_1 which is designated by 2a in Figure 4. The remaining data units $D_2 \ldots D_7$, which must also be transmitted to the second receiver E_1 to reproduce the data stream for the user of the second receiver E_1, are "taken" from the data set M_0 by the second receiver E_1 beginning at $t^0{}_1$. For the second receiver E_1, therefore, a much smaller number of the data units must be sent so that transmission bandwidth is saved.

If a third receiver E_2, for which the data stream is to be transmitted beginning at $t^0{}_2$, is additionally connected at time $t^0{}_2$, a data set M_2 transmitted for the third receiver E_2 comprises data units D_1 and D_2 which are designated by 3a and 3b, respectively, in Figure 4. The remaining data units $D_3 \ldots D_7$, which must also be transmitted to reproduce the data stream for the user of the third receiver E_2, are "taken" from the data set M_0 by the third receiver E_2 beginning at $t^0{}_2$, namely $D_3 \ldots D_7$ (1c to 1g in Figure 4).

If a fourth receiver E_3, for which the data stream is to be transmitted beginning at $t^0{}_3$, is additionally connected at time $t^0{}_3$, a data set M_3 transmitted for the fourth receiver E_3 comprises data units D_1 and D_3 which are designated by 4a and 4b, respectively, in Figure 4. The remaining data units D_2, $D_4 \ldots D_7$, which must also be transmitted to reproduce the data stream for the user of the third receiver E_2, are "taken" from the data set M_0, namely data units $D_4 \ldots D_7$ (1d to 1g), and from data set M_2,

namely data unit D_2 (3b in Figure 4), by the fourth receiver E_3 beginning at $t^0{}_2$.

One or more of the transmitted data units can be included in each case in one or more of the data sets M_j ($j \geq 0$) both in the exemplary embodiment described in conjunction with Figure 4 and in the exemplary embodiments explained in the text which follows.

The harmonic transmission schedule described with reference to Figure 4 has the disadvantage that the number of data units D_x to be sent in a time interval varies greatly. Thus, only one data unit (first data unit D_1) is transmitted in time interval 1, two in intervals 2,3 and 5, three in interval 4 and four in interval 6 (correspondingly continued for later intervals). This leads to peak loads, with the consequence that the transmission capacity from transmitter to the receivers E_0 … E_j must be matched to the greatest peak load if the transmission capacity is not utilized for a large proportion of the remaining transmission time.

Figure 5 shows a modification of the method according to Figure 4 which aims for a more uniform utilization of the transmission medium or transmission capacity, respectively: in each $(1 + p \cdot n)$th interval ($p \geq 0$), the system begins to transmit the data unit D_n. However, the sending is not concluded in the same interval (except in the case of the first data unit D_1) and, instead, the transmission is distributed to n intervals: the data unit D_1 is transmitted in each interval, and data unit D_2 in intervals 1 to 2, 3 to 4, 5 to 6, …, data unit D_3 in intervals 1

to 3, 4 to 6, 7 to 9, … . With a uniform distribution of a data unit D_x over the time intervals to be utilized, this means that the data unit D_1 is sent with single bandwidth on average, the second data unit D_2 with half the bandwidth on average, the third data unit D_3 with a third of the bandwidth on average etc. - that is to say the mth data unit D_m is sent with 1/m of the bandwidth on average which would be needed for transmitting the data unit D_m within one time interval. The respective starting times of the intervals again form the entry times $t^0{}_j$ ($j \geq 0$) for the receivers (compare Figure 5).

If it is not possible to distribute the transmission of the mth data unit D_m (uniformly) over m time intervals due to the technical transmission method and/or the number of data units D_x, a comparable effect, although with a slightly increased transmission volume, can be achieved as follows (compare Figure 6):

- if $m=2^z$ with $z \geq 0$ (i.e. m is a power of two), the mth data unit D_m is transmitted in each mth interval (compare Figure 6).
- Otherwise, all mth data units D_m for which $2^z < m < 2^{z+1}$ with $j \geq 0$ holds true, are transmitted precisely once between time intervals 2^z and 2^{z+1} and that in any (but uniform) order.

This means that the data units D_1, D_2, D_4 are sent in each, each second, each fourth etc. time interval. The data unit D_3 is in each case sent in the pauses between data units D_2, i.e. in time intervals 1,3,5,7 etc. Data units D_5 to D_7 with consecutive

numbers 5 to 7 are sent successively in each case once in the sequence of time intervals in which data unit D_4 is not sent, i.e. in time intervals 1, 2 and 3; 5, 6 and 7; 9, 10 and 11 etc.

Figure 7 shows a variation of the receiving funnels in the case where the data stream is transmitted to one or, respectively, to two receivers if the replay of the feature film is interrupted for a time t_u and is then continued again. In this case, a distinction can be made between two forms of receivers. In one form of receiver, the data units are still received and stored in the background during the interruption. This then leads to an expanded receiving funnel. In another form of receiver, the data units are not received during the interruption which leads to a displaced receiving funnel. In both cases, the receivers must not discard the data units already stored during the replay interruption.

The method described is based on the fact that data units D_x are transmitted in such a manner that the receivers receive all data units D_x required for the continuous display of the multimedia data stream, regardless of when they begin to receive them. The various transmission schedules described (compare Figures 4 to 6) explain by way of example when and how often a particular data unit D_x must be sent in order to meet the requirements of continuous reproduction of the multimedia stream. The result is, in particular, that the first data units D_1 of the multimedia stream are transmitted especially often and thus have

a high proportion of the bandwidth required for the method. For a transmission of a two-hour feature film having 7200 equally large data units D_x according to the method described, an optimum bandwidth was calculated which corresponds to about 9.45-times the transmitting bandwidth used when this feature film is transmitted in accordance with a conventional simple broadcasting of the feature film. The factor varies depending on the length of the feature film and the number of data units D_x.

A further improvement in the method described can be achieved with regard to the average transmitting bandwidth needed, by not transmitting a subset $D_1 \dots D_v$ ($1 \leq v < x$) of the data units D_x, for example the first 60 seconds of the feature film, in accordance with the method described but by already making it locally available to the receiver, e.g. as a file from which these data units $D_1 \dots D_v$ are read out. In this manner, the required bandwidth can be reduced from the factor of 9.5 to about 4.8 in the abovementioned example.

Figure 8 diagrammatically shows a multimedia data stream which comprises the data units D_x. The multimedia stream comprises a subset of data units $D_1, \dots, D_v$ and a subset of data units $D_{v+1}, \dots, D_x$. The subset of data units $D_{v+1}, \dots, D_x$ is transmitted to the receiver or all receivers in accordance with the method described above. At the beginning, the subset of data units $D_1, \dots, D_v$ is distributed to the receiver or all receivers so that the data units $D_1, \dots, D_v$ are present in the receiver or

all receivers before the beginning of a reproduction of the multimedia data stream. This reduces the transmission bandwidths needed during the transmission of the subset of data units D_{v+1}, …, D_x in accordance with the novel method described.

The prior distribution of the subset of data units D_1, …, D_v to the receiver or all receivers can be carried out in any manner according to usual methods, for example by means of web prefetching, by means of file distribution (e.g. via satellite), as part of an electronic programme guide, on CDs etc. The predistributed data units D_1, …, D_v can be transmitted encrypted when they are distributed.

Figure 9 diagrammatically shows a transmission schedule similar to the transmission schedule in Figure 4 for distributing the data units D_x. In distinction from the method described in conjunction with Figure 4, the data units D_1 and D_2 are at first not distributed to the receiver/s in accordance with the transmission schedule shown which is why they are drawn shaded. The further data units D_{v+1} ($v \geq 1$) are then transmitted to the receiver/s in accordance with the method which was described in conjunction with Figure 4. In this arrangement, the frequency of transmission of the further data units D_{v+1} and their order in time within the transmission schedule correspond to the position, in each case identified by means of the index v+1, of the further data units D_{v+1} ($v \geq 1$) in the data stream of the data units D_x (compare Figure 9). This correspondingly applies when the further

data units D_{v+1} ($v \geq 1$) are transmitted in accordance with the transmission schedules diagrammatically shown in Figures 5 or 6.

In the previous representation, it is assumed that all data units D_x of a feature film are always received by all receivers (which have begun to view the feature film) and that the receivers discard the data units which they do not need. In particular, all receivers are in this case considered to be equal, especially with respect to

- the receiving bandwidths demanded by them and
- the number of entry points $t^0{}_k$ offered to them (if no return channel is available).

This means all data units D_x of a feature film are transmitted in the same transmission channel and reach all receivers in this one transmission channel. However, different feature films are potentially transmitted in different transmission channels. This procedure is analogous to radio and television where different transmitters also use different transmission channels (in this case transmitting frequencies).

A distinction between different channels for different feature films/programmes can in this case assume any conceivable form: transmitting frequencies, time slices in frequencies, frequency ranges, bit and/or byte positions in continuous data streams and in data packets, network and/or transport addresses (for ATM, IP and any other networks) etc. These possibilities for implementing the discrimination between different channels

similarly applies to the subchannels presented in the text which follows.

<u>Subdivision into main channels and subchannels</u>

To be able to make the requirements for the receivers more heterogeneous and possibly to be able to offer different performances in conjunction therewith or as a supplement, the transmission of a feature film/programme in a channel can be conceivably supplemented by further substructuring of this channel into subchannels per feature film/programme.

In this case, not all data units D_x (slots) are sent in the same channel (the main channel) but distributed over a number of subchannels in accordance with the objectives. Among others, the following application scenarios can be implemented in this manner:

a) Customer-oriented advertising

A feature film is sprinkled with a number of advertising blocks W_1 to W_n distributed over its playing time. Such an advertising block W_k needs data units $D_{k,1}$ to $D_{k,m}$ for its transmission. If only one type of advertising is sent for the entire public, the advertising blocks are transmitted as part of one transmission channel. If the various types of advertising (per advertising block) are to be distinguished, the respective

data units are sent out in different subchannels. Each receiver selects one or more additional channel in addition to the main channel:

Channel	**Data units (slots)**
Main channel	Content of the feature film
Subchannel 1	"Sports" advertising
Subchannel 2	"Alcoholic drinks" advertising
…	
Subchannel w	"Domestic" advertising

Advertising is only one example here. Insertions of other types of information (for example short news, (regional) traffic information, different parts of a feature film (for example censored/uncensored etc.) can be implemented by using the same mechanism.

b) Different versions of a feature film (happy end versus tragic end)

After a certain time t_E in the film (all data units D_x with $x > E$), different contents are sent out in different channels. Each receiver individually decides which one of these channels he wishes to view.

Channel	Data units (slots)
Main channel	Content of the feature film up to D_E
Subchannel I	Data units D_x with $x > E$ for "happy end"
Subchannel II	Data units D_x with $x > E$ for "tragic end"
Subchannel III	Data units D_x with $x > E$ for "surprise end"

In this case, attention should be paid especially to the fact that a combination of the transmission of various endings by means of the invention leads to only an overproportionally smaller part of additional information having to be sent. According to the transmission schedules presented by way of example, data units with contents which are at the end of a feature film are transmitted distinctly more rarely than those with contents at the beginning of the feature film.

c) Simple feature film transmission compared with one expanded according to the invention

The transmission of the data contents can be designed in such a manner that, on the one hand, simple receivers (i.e. those not expanded according to the invention) can receive and reproduce the feature film, but only at the predetermined

starting time of the first transmission t^0_0, and, on the other hand, receivers according to the invention can begin viewing the feature film at different times.

To this end, for example, only the initial transmission of the feature film takes place on the main channel and each data unit is transmitted exactly once in succession. On another channel (here called subchannel I), the supplementary information is transmitted according to the invention. Simple receivers only receive the main channel, extended receivers, on the other hand, also receive the supplementary channel.

It is conceivable to transmit the feature film repeatedly completely in the main channel (for example in 2-hourly cycles).

Channel	**Data units (slots)**
Main channel	Transmit content of feature film once like normal broadcasting/normal television (data units 1a, 1b, …, 1g from Figure 4 if transmission according to the method shown in Figure 4)
Subchannel I	Supplementary information necessary for implementing the invention (all other data units from Figure 4)

This method cannot only be used for supporting conventional receivers; a combination with data encryption, for example, is

also conceivable. Thus, the main channel, for instance, can be transmitted unencrypted and thus is accessible to everybody but the subchannel is encrypted. A receiver without knowing the key can then only view the feature film at the first entry point but a receiver having knowledge of the key, in contrast, can start at any time and still view the feature film from the start. This makes it possible to create different models for different groups of customers in a simple manner (see also next section).

d) Different granularity of entry times

In extension of section c), the granularity of the entry points can also be adjusted by using different transmission channels. For example, as described in section c), the feature film can be transmitted only once in a main channel, the necessary supplementary information for being able to enter into the feature film every 10 minutes on subchannel I, the supplementary information for being able to begin viewing every minute on subchannel II etc. Naturally, any other combinations are also conceivable here.

Channel	Data units (slots)
Main channel	Transmit content of the feature film once like normal broadcasting/normal television (data units 1a, 1b, …, 1g from Figure 4 if transmission according to the method shown in Figure 4)
Subchannel I	Supplementary information for entry points every 10 minutes
Subchannel II	Supplementary information for entry points every minute

e) Different video quality (layered coding)

Finally, a technique is known which divides the content of a multimedia stream over different substreams: A basic data stream provides the basis for the viewing, supplementary data streams provide additional quality. Such methods are called "layered coding" and are known in various forms, especially from video data compression. It is possible here to offer for example different (temporal and spatial) resolutions of a video film, for example 15 fps (frames per second), 352x288, in the basic channel, 30fps with a resolution of 352x288 pixels in the first supplementary channel, 30fps with a resolution of 704x576 pixels in the second supplementary channel etc.

They can be used as a supplement to the invention and used in any combination with the abovementioned divisions into subchannels.

In the example following, only a mono-audio signal and a black/white picture is transmitted in the main channel, subchannel I supplies stereo sound and colour, subchannel 2 supplies HDTV quality and surround sound. Such an application can be appropriate, e.g. in the case of pay-TV programmes to offer different qualitative gradings of a film.

Channel	**Data units (slots)**
Main channel	Black/white picture, mono-audio
Subchannel I	Colour picture, stereo sound
Subchannel II	HDTV quality, surround sound

It should also be noted that, in principle, all the above scenarios can also be implemented without subdivision into various channels and subchannels, in that the transmitted data units are identified in accordance with the respective content and the receivers then only evaluate the contents desired by the consumer or, respectively, those which they are able to evaluate. However, the concept of the channels additionally provides greater efficiency and permits the heterogeneity of the receivers with respect to their receiving bandwidths initially mentioned.

Fault-tolerant transmission

In packet-switched networks, packet losses may occur. These are primarily dependent on the dimensioning of the network (bandwidths of the links) and the performance of the routers used. Whereas packet loss rates of 10% - 20% or more occur today in the Internet, which virtually does not make it appear to be realistic to transmit high-quality media streams, well-administered networks which are self-contained (such as satellite links, cable networks, intranetworks etc.) provide an environment with almost lossless data transmission.

Here, too, however, the occasional loss of one or more data units cannot be completely ruled out. For this reason, mechanisms must be provided which restore data units lost during their actual transmission in time at the receiver(s) before they have to be replayed.

Overall, there are two different methods, both of which can be combined with the invention:

If a return channel is available, the receivers can request missing data units again from the transmitter which then retransmits them. To detect missing data units, the data units must be numbered in the transmission schedule, for example in accordance with the order in which they are transmitted, or otherwise identified in such a manner that a receiver is capable of

- detecting a missing data unit (even if it is only to be reproduced in the remote future),
- determining, if necessary, whether the missing data unit is not transmitted at least one more time by the transmitter before the time of reproduction, in any case (so that no further action is required from the receiver) and
- if necessary, requesting the retransmission of the missing data unit from the transmitter,

potentially independently of the transmission schedule used by the transmitter at a time.

It must be noted here that in this variant of error correction, transmitting, receiving and reproduction time of a data unit are separated. In particular, an additional (artificial) delay can be inserted between reception and reproduction in order to ensure that data units, the transmission of which has taken place close to their reproduction time (applicable without additional delay) are still available in time for reproduction when they have to be retransmitted.

Independently of whether a return channel is available or not, the transmitted data units can be enriched by redundant supplementary information. If then a data unit is lost during a transmission, it can be reconstructed from the remaining data units and/or the redundant information with a probability dependent on the method and/or the quantity of redundant information used. Such methods are called forward error

correction (FEC). In the simplest case, each data unit is sent several times. More complex methods send for k data units (n-k) redundant units which are generated in such a manner that from n transmitted information units n-k can get lost and the content can still be completely reconstructed. Various other methods and combinations of different methods are also conceivable.

It should also be noted here that receiving and reproduction time can be separate if the receiver must still wait, if necessary, for the arrival of the redundant units (potentially sent later) before the media content can be replayed.

This, too, may be done by utilizing channels and subchannels: thus, the retransmissions can be transmitted, for instance, in a separate subchannel and different (preferably complementary) sets of FEC data can be sent in different subchannels.

The features of the invention disclosed in the above description, the drawing and the claims, can be of significance for the realization of the invention in its various embodiments both singly and in any combination.